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## (54) Embedding data in material

(57) A spatial domain image  $I$  produced by a source 1 is combined with watermark data  $R_i$  to produce a spatial domain watermarked image  $I'$ . The watermarked image is produced by an embedder 3 according to the equation

$$C_i' = C_i + \alpha \cdot R_i$$

where  $C_i$  and  $C_i'$  are wavelet transform coefficients of the image, and  $\alpha$  is a scaling factor,  $\alpha$  is chosen so that the watermark is imperceptible in the image and to resist removal of the watermark by unauthorised processing. It is desirable that  $\alpha$  has the smallest value which achieves that. If  $\alpha$  is too big the watermark is perceptible in the image; if it is too small the mark may not survive processing of the image.  $\alpha$  is determined from a trial decoding of the image  $I$  in a decoder 4. The decoding is that which would be used to decode the watermarked image  $I'$ . A value  $\alpha'$  is produced by a calculator S3-S8, to which an offset value is added by an adder S9 to produce  $\alpha$ . This produces values of  $\alpha$  over the image, which are used to scale the data  $R_i$  so as to conceal the data. An image is one example of material to which the invention is applicable.

The step of producing modified coefficient values  $C_i$  may not use coefficients of magnitude greater than a threshold  $T$  and does not use corresponding information symbols  $R_i$ . Alternatively, a threshold  $T_{clip}$  may be set. The scaling factor  $\alpha$  is calculated using clipped coeffi-

cient values and coefficients  $C_i$  of magnitude less than  $T_{clip}$ .

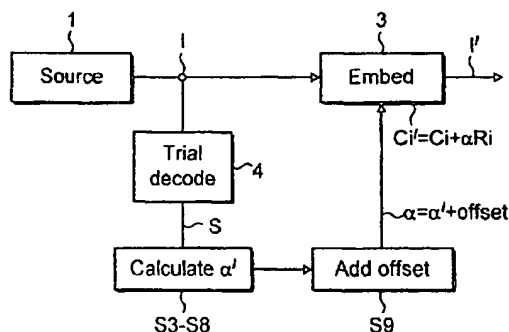


FIG. 1

## Description

[0001] The present invention relates to embedding data in material.

[0002] "Material" as used herein means information material represented by information signals which includes at least one or more of image material, audio material. Image material is generic to still and moving images.

## Steganography

[0003] Steganography is the embedding of data into material such as video material, audio material and data material in such a way that the data is imperceptible in the material.

[0004] Data may be embedded as a watermark in material such as video material, audio material and data material. A watermark may be imperceptible or perceptible in the material.

[0005] A watermark may be used for various purposes. It is known to use watermarks for the purpose of protecting the material against, or trace, infringement of the intellectual property rights of the owner(s) of the material. For example a watermark may identify the owner of the material.

[0006] Watermarks may be "robust" in that they are difficult to remove from the material. Robust watermarks are useful to trace the provenance of material which is processed in some way either in an attempt to remove the mark or to effect legitimate processing such as video editing or compression for storage and/or transmission. Watermarks may be "fragile" in that they are easily damaged by processing which is useful to detect attempts to remove the mark or process the material.

[0007] Visible watermarks are useful to allow e.g. a customer to view an image e.g. over the Internet to determine whether they wish to buy it but without allowing the customer access to the unmarked image they would buy. The watermark degrades the image and the mark is preferably not removable by the customer. Visible watermarks are also used to determine the provenance of the material into which they are embedded.

[0008] It is known to embed data in material. It is desirable to do that and allow the data to be removed from the material to avoid degrading the material. It is desirable to minimise any charges to the material needed to embed the data in it to avoid degrading the material. It is known to combine the data with the material, the data being scaled by a scaling factor which is chosen according to desired properties of the data when combined with the material. Those properties include one or more of: concealing the data in the material; making the data perceptible in the material; making the data, when embedded in the material, resistant to processing which, intentionally and unintentionally, removes or damages the embedded data.

[0009] According to a first aspect of the invention, there is provided a method of embedding data in material, the method comprising

combining a representation of the material with a function of the data and a scaling factor; wherein

the scaling factor is generated as a function of a trial decoding of the material,

the trial decoding comprising processing the material to recover data therefrom.

[0010] Thus the scaling factor can be chosen on the basis of an estimate of the result of a process (e.g. decoding) which will be performed on the combined material and data in practice so as to increase the likelihood that the data is recoverable from the material.

[0011] An embodiment of the first aspect of the invention further comprises the steps of:

combining, as a trial, a representation of the material with a function of the data and a trial scaling factor; and performing, as a trial, a predetermined process on the combined material and data;

wherein the scaling factor is generated as a function of a trial decoding of the processed combined material and data.

[0012] Thus the scaling factor can be chosen on the basis of an estimate of the result of a process (e.g. JPEG processing) which could be performed on the combined material and data in practice and which may damage the embedded data, so as to increase the likelihood that the data will not be damaged by such processing.

[0013] According to the first aspect of the invention, there is also provided a method of embedding data in material, the method comprising the steps of:

producing transform coefficients  $C_i$  representing a transform of the material;

producing a pseudo random symbol sequence (PRSS) having  $L$  symbols  $P_i$  of values  $+1$  and  $-1$ ;

calculating the correlation  $S = \sum C_i \cdot P_i$ , for  $i=1$  to  $i=L$ ; and

calculating modified coefficient values  $C'_i = C_i + \alpha \cdot P_i$ , where  $\alpha$  is calculated dependent on  $S$  and the value of the data bit to be embedded in the coefficient.

[0014] Preferably

$$\alpha = (\alpha' + \text{offset})$$

5

where  $\alpha' + \text{offset}$  is a function of the data bit to be embedded in the coefficient,  
and the method comprises the step of calculating modified coefficient values

10

$$Ci' = Ci + (\alpha' + \text{offset}) \cdot Pi$$

where

$\alpha' = 0$  if S is positive and the data to be concealed is a bit of a first value,

$\alpha' = 0$  if S is negative and the data to be concealed is a bit of a second value,

15

and otherwise  $\alpha'$  is a function of S such that  $\sum Ci' \cdot Pi$  has the correct sign to represent the bit to be encoded.

[0015] It will be noted that the calculation of the correlation  $S = \sum Ci \cdot Pi$ , for  $i=1$  to  $i=L$  is a form of trial decoding as in the said first aspect and the scaling factor is chosen in dependence on that correlation.

[0016] A further aspect of the invention provides a computer program product arranged to carry out one of the afore-said methods when run on a computer.

20

[0017] The invention also provides corresponding apparatus in other aspects of the invention.

[0018] According to a second aspect of the present invention, there is provided a method of embedding data in material, comprising the steps of:

producing transform coefficients  $Ci$  of the material;

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comparing the magnitudes of the coefficients with a threshold value T; and

producing, from the coefficients  $Ci$  and the said data modified, coefficient values  $Ci'$  which are modified by respective information symbols of a pseudo random symbol sequence modulated by the said data to be embedded;

wherein the said step of producing modified coefficient values does not use coefficients of magnitude greater than the said threshold T and does not use the corresponding information symbols.

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[0019] The data is detected at a decoder by correlating a pseudo random symbol sequence with the material in which the data is embedded. The data is represented by the sign of the correlation function. By not using, during embedding, coefficients which have a value greater than the threshold, any changes necessary to alter the coefficients to achieve the appropriate sign of the correlation value to represent a bit of the concealed data are minimised.

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[0020] According to the second aspect of the present invention, there is also provided a method for detecting data embedded in material, the detecting method comprising

receiving transform coefficients of the material;

comparing the magnitudes of the received coefficients with a threshold value T; and

correlating, the said coefficients with a respective symbols of a pseudo random symbol sequence to detect the said data, wherein the correlating step does not use coefficients of magnitude greater than the said threshold T and corresponding symbols of the pseudo random symbol sequence.

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[0021] Thus the detecting method is complementary to the embedding method.

[0022] The second aspect of the invention also provides the following a), and b):

45

a) Apparatus for embedding data in material comprising a transformer for producing transform coefficients  $Ci$  of the material;

a comparator for comparing the magnitudes of the coefficients with a threshold value T; and

a combiner for producing, from the coefficients  $Ci$  and the said data, modified coefficient values  $Ci'$  which are modified by respective information symbols of a pseudo random symbol sequence modulated by the said data to be embedded, wherein the combiner does not use coefficients of magnitude greater than the said threshold T and does not use the corresponding information symbols;

50

b) Apparatus for detecting data embedded in material comprising an input for receiving transform coefficients of the material;

a comparator for comparing the magnitudes of the received coefficients with a threshold T; and

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a correlator for correlating, the said coefficients with respective symbols of a pseudo random symbol sequence to detect the said data, wherein the correlation does not use coefficients of magnitude greater than the said threshold T and the corresponding symbols of the pseudo random symbol sequence.

**[0023]** Yet further, according to the second aspect of the invention, there is provided a method of detecting data embedded in material, the method comprising;

receiving transform coefficients of the material;

comparing the magnitudes of the received coefficients with a threshold  $T_{clip}$ ;

5 clipping, to a magnitude  $T_{clip}$ , the magnitude of coefficients of magnitude greater than the said threshold  $T_{clip}$ ; and correlating the clipped and unclipped coefficients with a pseudo random symbol sequence to detect data embedded in the material.

**[0024]** Yet further, apparatus according of the second aspect for detecting data embedded in material, comprises;

an input for receiving transform coefficients  $C_i$  of the material;

10 a comparator for comparing the magnitudes of the received coefficients with a threshold  $T_{clip}$ ;

means for clipping, to a magnitude  $T_{clip}$ , the magnitude of coefficients of magnitude greater than the said threshold  $T_{clip}$ ; and

a correlator for correlating the clipped and unclipped coefficients with a pseudo random symbol sequence to detect data embedded in the material.

15 **[0025]** This further aspect of the invention may involve only the detecting method and operates independently of the embedding method. By clipping large value coefficients to a preset smaller value, such coefficients no longer dominate the value of the correlation function needed to decode the embedded data.

**[0026]** However, preferably, there is provided:

20 a) A method of embedding data in material, the method comprising

receiving transform coefficients  $C_i$  representing the material;

comparing the magnitudes of the said transform coefficients  $C_i$  with a threshold  $T_{clip}$ ;

clipping, to the magnitude  $T_{clip}$ , the magnitudes of those of the coefficients having a magnitude exceeding  $T_{clip}$  to produce clipped coefficients; and

25 producing modified coefficients  $C_i'$  of values dependent on a scaling factor and the data to be embedded, and the scaling factor is calculated using the said clipped coefficients and the coefficients  $C_i$  of magnitude less than  $T_{clip}$ .

b) Apparatus for embedding data in material, the apparatus comprising:

30 an input for receiving transform coefficients  $C_i$  representing the material;

a comparator for comparing the magnitudes of the said transform coefficients with a threshold  $T_{clip}$ ;

a clipper for clipping, to the magnitude  $T_{clip}$ , the magnitudes of those of the coefficients having a magnitude exceeding  $T_{clip}$ ; and

35 a processor for producing modified coefficients  $C_i'$  of values dependent on a scaling factor and the data to be embedded, and the scaling factor is calculated using the said clipped coefficients and the coefficients  $C_i$  of magnitude less than  $T_{clip}$ .

**[0027]** Thus by clipping large value coefficients to a smaller value such coefficients no longer dominate the value of the function used to calculate the scaling factor.

40 **[0028]** The invention also provides a computer program product arranged to carry out one of the aforesaid methods when run on a computer.

**[0029]** For a better understanding of the present invention, reference will now be made by way of example to the accompanying drawings in which:

45 Figure 1 is a schematic block diagram of an embodiment of a watermarking system according to the present invention;

Figure 2 is a schematic block diagram of another embodiment of a watermarking system according to the present invention;

50 Figure 3A is a schematic diagram of a wavelet transform showing the relationship of the symbols of a pseudo random symbol sequence to coefficients ;

Figure 3B is a flow diagram of calculations performed by the system of Figure 2;

Figure 4 is a schematic block diagram of an illustrative watermark decoding and removal system;

Figure 5 is a flow diagram of calculations performed by the watermark remover and decoder of Figure 4;

55 Figure 6 is a schematic block diagram of a further embodiment of a watermarking system according to the present invention;

Figures 7 to 10A are schematic block diagram of subsystems of the system of Figure 6;

Figures 10B and 10C are flow diagrams illustrating a process for calculating  $\alpha$ ;

Figure 11A is a flow diagram of a modification, in accordance with the invention, of the flow diagram of Figure 3B;

Figure 11B is a diagram showing the relationship of coefficients  $C_i$  and symbols  $P_i$  of a pseudo random symbol sequence;

Figure 12 is a flow diagram of a modification, in accordance with the invention, of the flow diagram of Figure 5;

Figure 13 is a flow diagram of another modification, in accordance with the invention, of the flow diagram of Figure 5;

Figures 14 and 15 are diagrams explaining wavelet transforms; and

Figures 16 and 17 are diagrams showing a UMID and a data reduced UMID.

#### Overview

[0030] Referring to Figure 1, in the shown illustrative watermarking system, a spatial domain image  $I$  produced by a source 1 is combined with watermark data  $R_i$  to produce a spatial domain watermarked image  $I'$ . The watermarked image is produced by an embedder 3 according to the equation

$$C_i' = C_i + \alpha \cdot R_i$$

where  $C_i$  and  $C_i'$  are, for example, wavelet transform coefficients of the image, and  $\alpha$  is a parameter which is also referred to herein as a scaling factor.  $\alpha$  is chosen in this example so that the watermark is imperceptible in the image and to resist removal of the watermark by unauthorised processing. It is thus desirable that  $\alpha$  has the smallest value which achieves that. If  $\alpha$  is too big the watermark is perceptible in the image; if it is too small the mark may not survive processing of the image.

[0031] In accordance with this embodiment,  $\alpha$  is determined from a trial decoding of the original *unmarked* image  $I$  in a decoder 4. The decoding is that which would be used to decode the watermarked image  $I'$ . A value  $\alpha'$  is produced by a calculator S3-S8, to which an offset value is added by an adder S9 to produce  $\alpha$ . This produces values of  $\alpha$  over the image, which are used to scale the data  $R_i$  so as to conceal the data.

[0032] Figure 2 shows an example of the system of Figure 1 in which the calculation of  $\alpha$  also encodes  $R_i$ . Figure 6 shows an example of the system of Figure 1 in which the trial decoding takes place after a trial processing of the image data by a process which is likely to be applied to the watermarked image.

[0033] The data  $R_i$  in the examples given below is derived from a UMID. UMIDs are described in the section *UMIDs* below. As mentioned above, and in the examples given below, the image is subjected to a wavelet transform. Wavelet transforms are briefly discussed in the section *Wavelets* below.

#### Figure 2

[0034] Referring to Figure 2, for the purposes of explanation, it is assumed that the wavelet transform applied to the original spatial domain image results in a transform having four sub-bands of level 1: see the section *Wavelets* below. For ease of explanation the following description will refer only to the upper horizontal sub-band, but it will be appreciated that the present invention can be applied to any sub-band and may be applied to a plurality of sub-bands. The coefficients of the wavelet transform are denoted by  $C_i$  where  $i$  is the  $i^{\text{th}}$  coefficient of a sequence of  $J \times L$  coefficients where there are  $J$  bits of UMID data  $W_1$  to  $W_J$ . As will become apparent the  $J \times L$  coefficients correspond to symbols  $P_i$  of a Pseudo Random Symbol Sequence PRSS. Each UMID bit is embedded in  $L$  wavelet coefficients. Watermark data bit  $W_j$  is embedded in coefficients  $C_i$  for  $i = (j-1)L + 1$  to  $jL$ .

[0035] In this example a UMID is produced as the watermark data by a UMID generator 6. In this example the watermark is imperceptible. The data of the UMID is combined with the wavelet coefficients  $C_i$  in an embedder 3 in the manner described in detail in the following text. The transformed image together with the watermark  $C_i'$  is subjected to an inverse wavelet transform  $T^{-1}$ , (5) to produce a spatial domain watermarked image  $I'$ .

[0036] The watermark is decoded and, optionally, removed from the watermarked image using the illustrative decoding and removal system of Figure 4.

#### Trial decoder 4

[0037] A trial decoder 4 comprises a generator  $4_1$ , a converter  $4_2$ , and a correlator S1. The generator  $4_1$  produces a pseudo random symbol sequence (PRSS) which is pseudo random because the sequence whilst appearing random can be reliably reproduced. The binary sequence has a length of  $J \times L$  bits. The converter  $4_2$  converts the binary 1 and 0 to +1 and -1 respectively to produce a pseudo random symbol sequence (PRSS)  $P_i$  of values +1 and -1. The symbols of the PRSS are denoted herein by  $P_i$ , where  $i$  denotes the  $i^{\text{th}}$  symbol of the sequence which is  $J \times L$  symbols long. The correlator S1 produces correlation values

$$S_j = \sum C_i \cdot P_i, \text{ where the sum is taken over the range } i = (j-1)L + 1 \text{ to } jL \text{ for each of } j=1 \text{ to } J. \text{ (See Figure 3A.)}$$

Calculation of  $\alpha_j$  and embedding the UMID

[0038] There is one strength value  $\alpha_j$  for each UMID bit  $W_j$ .

[0039] The calculation of  $\alpha_j$  and the embedding of the UMID in the image operates in accordance with the flow diagram of Figure 3B. The embedder 3 calculates a function

$$C_i' = C_i + \alpha_j P_i \quad \text{for } i = (j-1)L + 1 \text{ to } jL \text{ for each of } j=1 \text{ to } J.$$

where  $C_i'$  is an  $i$ th wavelet coefficient modified to encoded a bit of watermarking data; and  $\alpha_j$  is the scaling factor, the value of which depends on:

- a) the value 1 or 0 of a bit  $W_j$  of the UMID to be encoded in modified coefficient  $C_i'$ ; and
- b) the sign of the correlation value  $S_j = \sum C_i P_i$ , for  $i = (j-1)L + 1$  to  $jL$  for each of  $j=1$  to  $J$ , produced by the trial decoder 4; and
- c) the offset value, which is  $\pm 1$  in this example, so  $\alpha_j = \alpha_j' + \text{offset}_j$ .

[0040] The principle of operation is that a watermark bit  $W_j=1$  is encoded as a positive correlation value and  $W_j=0$  is encoded as a negative correlation value ( or vice versa).  $\alpha_j$  is chosen to ensure the value of a correlation  $S_j' = \sum C_i' P_i$  for  $i = (j-1)L + 1$  to  $jL$  for each of  $j=1$  to  $J$ , performed at the decoder has the correct sign to represent the value of bit  $W_j$ . If the correlation  $S_j$  performed at the encoder has the correct sign, then  $\alpha_j' = 0$  otherwise  $\alpha_j'$  is modified to ensure that the correlation  $S_j' = \sum C_i' P_i$  performed at the decoder has the correct sign.

[0041] Thus referring to Figure 3B:-

$$\text{A value } \alpha_j' = \alpha_j - \text{offset}_j.$$

[0042] Step S1 (correlator S1 of Figure 2) calculates the correlation value  $S_j = \sum C_i P_i$ , where the sum is taken over the range  $i = (j-1)L + 1$  to  $jL$  for a sequence  $i = (j-1)L + 1$  to  $jL$  of coefficients  $C_i$  and PRSS bits  $P_i$ . (Note that 'symbols'  $P_i$  have values  $+1$  and  $-1$  to ensure that bits of value 0 produced by the generator 4, contribute to the value of  $S_j$ .) Step S1 is a trial decoding with a trial value of  $\alpha_j = 0$ .

[0043] Step S2 determines whether the bit  $W_j$  of the UMID generated by generator 6 is 1 or 0. It will be appreciated that the bit  $W_j$  is in effect encoded over  $L$  coefficients. If  $W_j=1$  then steps S3 to S5 and S9+ are followed. These steps are implemented by blocks S3-S8 and S9 in figure 2.

[0044] Step S3 determines the sign of the correlation  $S_j$ . If the sign is positive and the bit  $W_j$  is 1 then

$$\text{at step S4 } \alpha_j' = 0.$$

[0045] If the sign determined at step S3 is negative but the bit  $W_j=1$  (which should be encoded by  $S_j$  positive), then

$$\text{at step S5 } \alpha_j' = -S_j/(L-1).$$

[0046] At step S9+, the offset  $+1$  is added to ensure that  $\alpha_j$  is positive if  $S_j=0$  and to increase robustness.. It should be noted that the offset is a signed value ( $+1$ ) in this example.

[0047] If  $W_j=0$  then steps S6 to S8 and S9- are followed. These steps are implemented by blocks S3-S8 and S9 in figure 2.

[0048] Step S6 determines the sign of the correlation  $S_j$ . If the sign is negative and the bit  $W_j$  is 0 then

$$\text{at step S7 } \alpha_j' = 0.$$

[0049] If the sign determined at step S6 is positive but the bit  $W_j=0$  (which should be encoded by  $S$  negative), then

$$\text{at step S8 } \alpha_j' = -S_j/(L-1).$$

[0050] At step S9 the offset -1 is added to ensure that  $\alpha_j$  is negative if  $S_j=0$  and to increase robustness. It should be noted that the offset is a signal value (-1) in this example.

[0051] At step S10 the value  $C_i' = C_i + \alpha_j P_i$  is calculated for  $i = (j-1)L + 1$  to  $jL$ .

[0052] The value  $\alpha_j = -S_j/(L-1)$  is an example. The value  $\alpha_j$  could be  $\alpha_j = -S_j/L$  as another example.

[0053] At step S9 an offset of +1 could be subtracted from  $\alpha_j$ .

#### Watermark Decoding and Removing System ( Figures 4 and 5)

[0054] Referring to Figure 4, the watermark removing and decoding system has an input for receiving a spatial domain watermarked image  $I'$  from the system of Figure 1. The image may have been subject to image processing (not shown) between production by the system of Figure 1 and the receipt by the system of Figure 4.

[0055] The received image is transformed by a wavelet transformer 46 (T) to produce wavelet coefficients  $C_i'$ . The coefficients  $C_i'$  are provided to a synchroniser 8 which correlates the coefficients with a PRSS generated by a generator 10. The synchroniser 8 and the PRSS generator 10 carry out, in known manner, correlations with differing shifts of the PRSS relative to the coefficients to determine the position in the watermarked transformed image of the original PRSS produced at the watermarking system of Figure 1. Once synchronisation has been achieved the coefficients  $C_i'$  are correlated with the PRSS in another correlator 12 to produce the correlation value

$$S_j' = \sum C_i' \cdot P_i \text{ for } i = (j-1)L + 1 \text{ to } jL \text{ for each of } j=1 \text{ to } J.$$

where  $P_i$  has values +1 and -1.

[0056] The correlation value  $S_j'$  is provided to a decoder 14 and to a remover 16, the operations of which will be described with reference to the flow diagram of Figure 5. The decoder 14 extracts the UMID from the image. The watermark is removed by the remover 16. The resulting restored transformed image is subject to an inverse wavelet transform ( $T^{-1}$ ) in an inverse transformer 18.

[0057] Referring to Figure 5, the synchronisation of the PRSS with the received transformed image occurs at step S12. At step S14, the correlation value

$$S_j' = \sum C_i' \cdot P_i \text{ for } i = (j-1)L + 1 \text{ to } jL.$$

is calculated over a length L of the PRSS.

[0058] At step S16, the sign of the value  $S_j'$  is determined. If  $S_j'$  is negative then the bit of the watermark, (the UMID in this example), is 0. If  $S_j'$  is positive the bit of the watermark is 1.

[0059] At step S18,

$$\alpha_j = S_j' / (L-1)$$

is calculated from  $S_j'$ . (This calculation may be an approximation because it assumes that  $\sum C_i \cdot P_i = 0$ )

[0060] At step S22,  $C_i = C_i' - \alpha_j P_i$  is calculated for  $i = (j-1)L + 1$  to  $jL$ .

[0061] If, in the embedding process,  $\alpha_j$  is calculated as  $-\frac{S_j}{L}$  at the step S5 or S8, then in the decoding process  $\alpha_j'$  is calculated as  $S_j'/L$  at step S18.

#### Modifications.

##### a). Threshold on the values of $C_i$ and $C_i'$ (Figure 11A, Figure 12)

[0062] In a modification of the embodiment described above, the values of the coefficients  $C_i$  are compared (S40) with a threshold value  $Th_e$  at the embedder of Figure 2, and the values of the coefficients  $C_i'$  are compared S41 with a threshold value  $Th_d$  at the remover 16 of Figure 4 and also at the decoder 14 of Figure 4. If the value of a coefficient exceeds the threshold, that coefficient is not used (S42, S43) in establishing the correlation value  $S_j$  or  $S_j'$ .  $Th_e$  and  $Th_d$  may be equal, but it has been found that  $Th_d$  is preferably greater than  $Th_e$ .

[0063] By way of a simple example, assume that the PRSS has length  $L=4$  and symbols  $P_1$  to  $P_4$  have values +1, -1, -1, and +1. Then referring to Table 1 three examples are shown.

Table 1

		P1 C1	P2 C2	P3 C3	P4 C4	Sj, $\alpha_j'$ Wj=0
	PI	+1	-1	-1	+1	
Ex1	CI	-2	-5	+1	-3	-1, 0
Ex2	CI	-2	-25	+1	-3	+19, -19/3
Ex3	CI	-2		+1	-3	-6, 0

Example 1 (Ex1)

[0064] The coefficients Ci have values shown. If the value of the bit Wj of the watermark to be encoded is 0 then according to Figure 3, Sj=-1 and so  $\alpha_j'=0$ .

Example 2 (Ex2)

[0065] However if as shown in example 2 the coefficient C2 has a value -25 than Sj=+19 and  $\alpha_j'=-19/3$ . Large values of  $\alpha_j'$  may cause the watermark to be perceptible when it should be imperceptible.

Example 3 (Ex3)

[0066] In accordance with an embodiment of the present invention, thresholds  $+Th_e$  and  $-Th_e$  are set. The magnitude of  $Th_e$  may be about 6 for the above example. In practice it is set empirically. Thus as shown in Table 1, the coefficient C2 is not used in the calculation of Sj, and also the corresponding symbol of the PRBS is also not used. As a result Sj=-6 and  $\alpha_j'=0$ . Thus if the magnitude of a coefficient exceeds the threshold the coefficient is not used.

[0067] Now, referring to Figure 11A, in accordance with this embodiment, the following procedure takes place at the embedder before step S1 of Figure 3B.

[0068] At step S40, the magnitude of the coefficient value Ci is compared with the threshold  $Th_e$ . If the magnitude of Ci is greater than the threshold  $Th_e$  then at step S42 Ci is not used. Otherwise at step S44 Ci is used to calculate Ci' as described with reference to Figure 3B. Referring to Figure 11B, it will be recalled that each symbol Pi of the PRSS is associated with a coefficient Ci. When a coefficient Ci is not used because it exceeds the threshold, the corresponding symbol Pi generated by the generator 4 is also not used as indicated by the blocks Ci and Pi in Figure 11B.

b) Clipping coefficient values (Figure 13)

[0069] In an alternative modification, the values of the modified coefficients Ci' are clipped at the decoder of Figure 4 if they exceed (S80) a threshold value of magnitude  $Th_{clip}$ . Thus coefficient values greater than the threshold are reduced to a predetermined value e.g.  $Th_{clip}$ . For example referring to Table 1 Example 2, the coefficient C2 (-25) is clipped to say  $+Th_{clip}$  e.g. -6 at the decoder. If  $C_i > +Th_{clip}$ , then  $C_i$  is set to  $+Th_{clip}$  (step S84).

[0070] If  $|Th_{clip}| = 6$  is only an example and in practice may have other values set by experiment.

[0071] Such clipping may or may not be performed also at the embedder of Figure 2.

[0072] In the embedder shown in Figure 2 it is not performed. However, in another embodiment, the procedure of Figure 13 may be applied prior to step S1 in Figure 3B.

[0073] The clipping is performed only for the purpose of calculating the parameter  $\alpha_j$ . The coefficients Ci to which  $\alpha_j$  is added do not have clipped values.

Limiting  $\alpha_j'$ 

[0074] The value of  $\alpha_j'$  may be limited to be within a present range determined by upper and lower bounds.

Trial processing and decoding- Figure 6

[0075] Referring to Figure 6, an unmarked spatial domain image I is applied to an embedder 60. An example of the embedder is shown in Figure 8. The embedder calculates

$$Ci' = Ci + \alpha_{Tj} Ri \text{ for } i = (j-1)L + 1 \text{ to } jL \text{ for each of } j=1 \text{ to } J.$$

where:  $Ci$  is a wavelet transform coefficient of the image;  $Ri$  is a watermarking symbol formed by combining a PRSS of  $JxL$  bits  $Pi$  with watermark data  $Wj$ . Symbol  $Ri$  has a value + or - 1;  $\alpha_{Tj}$  is a trial value of the scaling factor for UMID ( or watermark ) data bit  $Wj$ . In this example  $\alpha_{Tj}$  is initialised to 1. Figure 7 shows an example of a subsystem, for producing  $Ri$ .

[0076] The embedder also includes an inverse transformer which produces a spatial domain watermarked image  $Iw$ .

[0077] The image  $Iw$  is processed by a processor 62 to produce a processed spatial domain image  $Ip$ . The processor 62 is chosen to process the image according to a process which the watermarked image is likely to encounter in use, and/or a process which may be applied to the image to deliberately remove or damage the watermark. JPEG processing using DCT transforms is a process which is known to be potentially damaging to some watermarks.

[0078] A decoder 64, an example of which is shown in Figure 9, decodes the processed image  $Ip$ . The decoder may extract the watermark data  $Wj$ . The decoder produces correlation values

$$Sip,j' = \sum Cip.Pi \text{ for } i = (j-1)L + 1 \text{ to } jL \text{ for each of } j=1 \text{ to } J.$$

where  $Cip$  are wavelet coefficients of the processed image  $Ip$  and the sum is calculated over a length  $L$  of a PRSS having  $JxL$  bits  $Pi$ .

[0079] A calculator 66 calculates a new value of  $\alpha_j$  based on the magnitude of  $Sip,j$  to produce new trial values of  $\alpha_{t+nj}$  which is used as a new value in the trial embedder 60.  $n$  is the number of iterations used to calculate a final value  $\alpha_{t+nj}$  which is applied to an embedder 69.  $n = 0, 1, 2$ . Several iterations may be used. Preferably the number of iterations is limited to a predetermined number, e.g. 4, because the process 62 may be non-linear (JPEG processing is non-linear) and it is then unlikely that the iterations will converge to steady values of  $\alpha_{t,j}$ .

[0080] Examples of (a) the calculator 66 and (b) the embedder 69 are shown in Figures 10 and 8 respectively.

#### Calculating $Ri$ , Figure 7.

[0081] A PRSS generator 71 produces a PRSS having  $JxL$  bits  $Pi$ . A UMID generator 72 produces a UMID having bits  $Wj$ . In a modulator 73, each bit  $Wj$  of the UMID modulates, and is thus spread over, an  $L$  bit sequence of the PRSS. A data converter 74 converts the binary values 1 and 0 at the output of the modulator to produce symbols  $Ri$  of value +1 and -1 respectively.

#### Embedder 60 and 69,- Figure 8.

[0082] The embedder of Figure 8 comprises a wavelet transformer 82 which produces the wavelet coefficients  $Ci$  and an inverse transformer 85. A multiplier 84 calculates  $\alpha_{t+nj}.Ri$ . An adder 83 adds  $\alpha_{t+nj}.Ri$  to  $Ci$  to produce.

$$Ci' = Ci + \alpha_{t+nj}.Ri \text{ for } i = (j-1)L + 1 \text{ to } jL \text{ for each of } j=1 \text{ to } J.$$

[0083] Thus each coefficient  $Ci$  is modified by a value of  $\alpha$  associated with that coefficient and by one symbol  $Ri$ .

[0084] Unlike the example of Figures 2 and 3,  $Ri$  is a symbol stream comprising the PRSS modulated by the data to be embedded, and  $\alpha$  is an unsigned magnitude.

#### Decoder 64-Figure 9

[0085] The decoder has a wavelet transformer 91 which produces wavelet coefficients  $Cip$  from the processed image  $Ip$ . A synchroniser 92 operating in known manner shifts the phase of the PRSS produced by a PRSS generator 93 so that it is in phase with the PRSS in the image  $Ip$ . A data converter 94 converts the PRSS values  $Pi$  to +1 and -1. A correlator calculates a correlation value

$$Sip,j = \sum Cip.Pi \text{ for } i = (j-1)L + 1 \text{ to } jL \text{ for each of } j=1 \text{ to } J.$$

[0086] A decoder 96 determines the values of the data bits  $Wj$  from the sign of the correlation values  $Sip,j$ .

Calculating  $\alpha$ -Figures 10A, 10B and 10C

[0087] Referring to Figure 10A, new values of  $\alpha_{t+1,j}$  are calculated by adding an offset to a basic fixed value  $\alpha_{t,j}$  in an adder 99. The offsets are produced by an offset generator 95. The generator responds to an offset control value produced by a processor 97. The processor controls the offset and thus the values of  $\alpha_{t+1,j}$  in dependence on the correlation values  $Sip,j$ .

[0088] Figures 10B and 10C illustrate examples of the operation of the processor.

[0089] Referring to Figure 10B, the correlation values  $Sip,j$  are compared at step S30 with the corresponding symbols  $W_j$ . The correlation values  $Sip,j$  are positive and negative, a positive value indicates a symbol 1 and a negative value a symbol 0, (if the values  $Sip$  are unchanged by the processing in processor 62). If the signs of  $Sip,j$  correctly represent  $W_j$  then the magnitude of  $Sip,j$  is compared with an upper threshold  $Th$ . If  $|Sip,j| > Th$  then the value of  $\alpha_j$  is reduced for the next iteration  $\alpha_{t+1,j}$ . If  $|Sip,j|$  is not greater than the threshold  $\alpha_j$  either remains unchanged for the next iteration  $\alpha_{t+1,j}$  or is used as the final value of  $\alpha_{t,j}$ .

[0090] If the sign of  $Sip,j$  indicates the incorrect value for  $W_j$ , then  $\alpha_j$  is increased for the next iteration  $\alpha_{t+1,j}$ .

[0091] Referring to Figure 10C, at step S40 a value  $(Sip,j)/L$  is calculated from  $Sip,j$ . That is the average correlation value over  $L$  symbols. That value is used as  $\alpha_{t+1,j}$  for the next iteration. Preferably  $\alpha_{t+1,j}$  is compared with an upper threshold  $Th$  at step S42. If  $\alpha_{t+1,j}$  exceeds  $Th$ , then  $\alpha_{t+1,j}$  is reduced. Otherwise it is compared (S46) with a lower threshold  $TL$ . If  $\alpha_{t+1,j}$  is less than  $TL$ ,  $\alpha_{t+1,j}$  is increased (S48) otherwise it is unchanged (S49).

Modifications.Other transforms

[0092] Whilst the invention has been described by way of example with reference to Wavelet transforms, it may be used with other transforms for example DCT.

Other material

[0093] Whilst the invention has been described by way of example with reference to material comprising images, e.g. video material, it may be applied to other material, for example audio material and data material.

Other Watermark data.

[0094] Whilst the invention has been described by way of example with reference to UMIDs as the watermark data, it may be used with other data as the watermark.

Wavelets

[0095] Wavelets are well known and are described in for example "A Really Friendly Guide to Wavelets" by C Valens, 1999 and available at <http://perso.wanadoo.fr/polyvalens/clemens/wavelets/wavelets.html>.

[0096] Valens shows that the discrete wavelet transform can be implemented as an iterated filter bank as used in sub-band coding, with scaling of the image by a factor of 2 at each iteration.

[0097] Thus referring to Figure 12, a spatial domain image is applied to a set of high pass HP and low pass LP filters. At level 1, the first stage of filtering, the image is filtered horizontally and vertically and, in each direction, scaled down by a factor of 2. In level 2, the low pass image from level 1 is filtered and scaled in the same way as in level 1. The filtering and scaling may be repeated in subsequent levels 3 onwards.

[0098] The result is shown schematically in Figure 11. Figure 11 is a representation normal in the art. At level one the image is spatially filtered into four bands: the lower horizontal and vertical band,  $lH_1, lV_1$ ; the upper horizontal band  $hH_1, lV_1$ ; the upper vertical band  $lH_1, hV_1$ ; and the upper horizontal and vertical band,  $hH_1, hV_1$ . At level 2, the lower horizontal and vertical band,  $lH_1, lV_1$  is filtered and scaled into the lower horizontal and vertical band,  $lH_2, lV_2$ ; the upper horizontal band  $hH_2, lV_2$ ; the upper vertical band  $lH_2, hV_2$ ; and the upper horizontal and vertical band,  $hH_2, hV_2$ . At level 3 (not shown in Figure 11), the lower horizontal and vertical band,  $lH_2, lV_2$  is further filtered and scaled.

UMIDs

[0099] The UMID or Unique Material Identifier is described in SMPTE Journal March 2000. Referring to Figure 13, an extended UMID is shown. It comprises a first set of 32 bytes of basic UMID and a second set of 32 bytes of signature metadata.

[0100] The first set of 32 bytes is the basic UMID. The components are:

- A 12-byte Universal Label to identify this as a SMPTE UMID. It defines the type of material which the UMID identifies and also defines the methods by which the globally unique Material and locally unique Instance numbers are created.
- A 1-byte length value to define the length of the remaining part of the UMID.
- A 3-byte Instance number which is used to distinguish between different 'instances' of material with the same Material number.
- A 16-byte Material number which is used to identify each clip. Each Material number is the same for related instances of the same material.

[0101] The second set of 32 bytes of the signature metadata as a set of packed metadata items used to create an extended UMID. The extended UMID comprises the basic UMID followed immediately by signature metadata which comprises:

- An 8-byte time/date code identifying the time and date of the Content Unit creation.
- A 12-byte value which defines the spatial co-ordinates at the time of Content Unit creation.
- 3 groups of 4-byte codes which register the country, organisation and user codes

[0102] Each component of the basic and extended UMIDs will now be defined in turn.

#### The 12-byte Universal Label

[0103] The first 12 bytes of the UMID provide identification of the UMID by the registered string value defined in table 1.

Table 1:

Specification of the UMID Universal Label		
Byte No.	Description	Value (hex)
1	Object Identifier	06h
2	Label size	0Ch
3	Designation: ISO	2Bh
4	Designation: SMPTE	34h
5	Registry: Dictionaries	01h
6	Registry: Metadata Dictionaries	01h
7	Standard: Dictionary Number	01h
8	Version number	01h
9	Class: Identification and location	01h
10	Sub-class: Globally Unique Identifiers	01h
11	Type: UMID (Picture, Audio, Data, Group)	01, 02, 03, 04h
12	Type: Number creation method	XXh

[0104] The hex values in table 1 may be changed: the values given are examples. Also the bytes 1-12 may have designations other than those shown by way of example in the table. Referring to the Table 1, in the example shown byte 4 indicates that bytes 5-12 relate to a data format agreed by SMPTE. Byte 5 indicates that bytes 6 to 10 relate to "dictionary" data. Byte 6 indicates that such data is "metadata" defined by bytes 7 to 10. Byte 7 indicates the part of the dictionary containing metadata defined by bytes 9 and 10. Byte 10 indicates the version of the dictionary. Byte 9 indicates the class of data and Byte 10 indicates a particular item in the class.

[0105] In the present embodiment bytes 1 to 10 have fixed preassigned values. Byte 11 is variable. Thus referring to Figure 14, and to Table 1 above, it will be noted that the bytes 1 to 10 of the label of the UMID are fixed. Therefore they may be replaced by a 1 byte 'Type' code T representing the bytes 1 to 10. The type code T is followed by a length code L. That is followed by 2 bytes, one of which is byte 11 of Table 1 and the other of which is byte 12 of Table 1, an

instance number (3 bytes) and a material number (16 bytes). Optionally, the material number may be followed by the signature metadata of the extended UMID and/or other metadata.

[0106] The UMID type (byte 11) has 4 separate values to identify each of 4 different data types as follows:

- 5        '01h' = UMID for Picture material
- '02h' = UMID for Audio material
- '03h' = UMID for Data material
- '04h' = UMID for Group material (i.e. a combination of related essence).

- 10    [0107] The last (12th) byte of the 12 byte label identifies the methods by which the material and instance numbers are created. This byte is divided into top and bottom nibbles where the top nibble defines the method of Material number creation and the bottom nibble defines the method of Instance number creation.

#### Length

- 15    [0108] The Length is a 1-byte number with the value '13h' for basic UMIDs and '33h' for extended UMIDs.

#### Instance Number

- 20    [0109] The Instance number is a unique 3-byte number which is created by one of several means defined by the standard. It provides the link between a particular 'instance' of a clip and externally associated metadata. Without this instance number, all material could be linked to any instance of the material and its associated metadata.
- [0110] The creation of a new clip requires the creation of a new Material number together with a zero Instance number. Therefore, a non-zero Instance number indicates that the associated clip is not the source material. An Instance
- 25    number is primarily used to identify associated metadata related to any particular instance of a clip.

#### Material Number

- 30    [0111] The 16-byte Material number is a non-zero number created by one of several means identified in the standard. The number is dependent on a 6-byte registered port ID number, time and a random number generator.

#### Signature Metadata

- 35    [0112] Any component from the signature metadata may be null-filled where no meaningful value can be entered. Any null-filled component is wholly null-filled to clearly indicate a downstream decoder that the component is not valid.

#### The Time-Date Format

- 40    [0113] The date-time format is 8 bytes where the first 4 bytes are a UTC (Universal Time Code) based time component. The time is defined either by an AES3 32-bit audio sample clock or SMPTE 12M depending on the essence type.
- [0114] The second 4 bytes define the date based on the Modified Julian Data (MJD) as defined in SMPTE 309M. This counts up to 999,999 days after midnight on the 17th November 1858 and allows dates to the year 4597.

#### The Spatial Co-ordinate Format

- 45    [0115] The spatial co-ordinate value consists of three components defined as follows:
  - Altitude: 8 decimal numbers specifying up to 99,999,999 metres.
  - Longitude: 8 decimal numbers specifying East/West 180.00000 degrees (5 decimal places active).
  - 50    • Latitude: 8 decimal numbers specifying North/South 90.00000 degrees (5 decimal places active).

[0116] The Altitude value is expressed as a value in metres from the centre of the earth thus allowing altitudes below the sea level.

- 55    [0117] It should be noted that although spatial co-ordinates are static for most clips, this is not true for all cases. Material captured from a moving source such as a camera mounted on a vehicle may show changing spatial co-ordinate values.

**Country Code**

[0118] The Country code is an abbreviated 4-byte alpha-numeric string according to the set defined in ISO 3166. Countries which are not registered can obtain a registered alpha-numeric string from the SMPTE Registration Authority.

**Organisation Code**

[0119] The Organisation code is an abbreviated 4-byte alpha-numeric string registered with SMPTE. Organisation codes have meaning only in relation to their registered Country code so that Organisation codes can have the same value in different countries.

**User Code**

[0120] The User code is a 4-byte alpha-numeric string assigned locally by each organisation and is not globally registered. User codes are defined in relation to their registered Organisation and Country codes so that User codes may have the same value in different organisations and countries.

**Claims**

1. A method of embedding data in material, the method comprising  
 combining a representation of the material with a function of the data and a scaling factor; wherein  
 the scaling factor is generated as a function of a trial decoding of the material,  
 the trial decoding comprising processing the material to recover data therefrom.
2. A method according to claim 1, wherein the step of combining involves modulating a pseudo random symbol sequence with the said data and the trial decoding comprises the step of correlating a pseudo random symbol sequence with the said representation of the material, and the scaling factor is generated in dependence on the result of the correlation.
3. A method according to claim 1 or 2, further comprising:  
 combining, as a trial, a representation of the material with a function of the data and a trial scaling factor; and  
 performing, as a trial, a predetermined process on the combined material and data;  
 wherein the scaling factor is generated as a function of a trial decoding of the processed combined material and data.
4. A method of embedding data bits in material, the method comprising the steps of:  
 producing transform coefficients  $C_i$  representing a transform of the material;  
 producing a pseudo random symbol stream having  $L$  symbols  $P_i$  of values  $+1$  and  $-1$ ;  
 calculating a correlation  $S = \sum C_i \cdot P_i$ , for  $i=1$  to  $i=L$ ; and  
 calculating modified coefficient values  $C_i' = C_i + \alpha \cdot P_i$ , where  $\alpha$  is calculated dependent on  $S$  and the value of the data bit to be embedded in the coefficient.
5. A method according to claim 4 wherein  

$$\alpha = (\alpha' + \text{offset})$$
 where  $\alpha' + \text{offset}$  is a function of the data bit to be embedded in the coefficient,  
 $\alpha' = 0$  if  $S$  is positive and the data to be concealed is a symbol of a first value,  
 $\alpha' = 0$  if  $S$  is negative and the data to be concealed is a symbol of a second value, and  
 otherwise  $\alpha'$  is a function of  $S$  such that  $\sum C_i' \cdot P_i$  has the correct sign to represent the symbol to be encoded.
6. A method according to claim 5, wherein the first value is "1" and the second value is "0".

7. A method according to claim 4, 5 or 6 wherein the said function of S is

$$\alpha' = -S/(L-1) \text{ or } \alpha' = -S/L.$$

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8. A method according to claim 4, 5, 6 or 7, wherein the magnitude of the offset is greater than or equal to zero.

9. A method according to claim 8, wherein the magnitude of the offset is one.

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10. A method according to any preceding claim, wherein the said coefficients are coefficients of a wavelet transform of the material.

11. A method according to any preceding claim wherein the data to be embedded includes a UMID.

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12. A method of removing data from material, which data has been embedded by the method of any one of claims 4 to 11, the method comprising the steps of:

calculating the correlation  $S' = \sum C_i' \cdot P_i$  for  $i=1$  to  $L$  where  $P_i$  are the bits of the PRSS and have values +1 and -1;

calculating  $\alpha_r$  as a function of  $S'$ ; and

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calculating  $C_i = C_i' - \alpha_r \cdot P_i$  to recover the unmodified coefficients  $C_i$ .

13. A method according to claim 12, wherein  $\alpha_r = S'/(L-1)$  or  $\alpha_r = (S'/L)$ .

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14. A method according to claim 12 or 13, further comprising deriving the symbols of the concealed data from  $S'$ , where if  $S'$  is positive a symbol is of the first value and if  $S'$  is negative a symbol is of the second value.

15. A method according to claim 12, 13 or 14, comprising the step of generating and synchronizing a reference pseudo random symbol sequence with the pseudo random symbol sequence of the embedded data.

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16. A computer program product arranged to carry out the method of any preceding claim when run on a computer.

17. Apparatus for embedding data in material, the apparatus comprising:

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a combiner for combining a representation of the material with a function of the data and a scaling factor;

a decoder for decoding, as a trial, the material to recover data therefrom; and

a generator for generating the scaling factor as a function of the trial decoding of the material.

18. Apparatus according to claim 17, wherein:

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the combiner includes a modulator for modulating a pseudo random symbol sequence with the said data;

the trial decoder comprises a correlator for correlating the pseudo random binary sequence with the said material; and

the scaling factor generator is arranged to generate the scaling factor in dependence on the result of the correlation.

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19. Apparatus according to claim 17 or 18, wherein the combiner is arranged to combine, as a trial, a representation of the material with a function of the data and a trial scaling factor; and further comprising:

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a processor for performing, as a trial, a predetermined process on the combined material and data;

wherein the scaling factor is generated as a function of a trial processing of the processed combined material and data so as to recover the said data.

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20. Apparatus for embedding data in material, the apparatus comprising:

a transformer for producing transform coefficients  $C_i$  representing a transform of the material;

a generator for producing a pseudo random symbol stream having  $L$  bits  $P_i$ ;

an input for receiving symbol representing the data to be concealed; and  
a data embedder arranged to  
calculate a correlation  $S = \sum C_i \cdot P_i$ , for  $i=1$  to  $i=L$  and  
calculate modified coefficient values  $C_i' = C_i + \alpha \cdot P_i$ , where  $\alpha$  is calculated dependent on  $S$  and the value of  
the data bit to be embedded in the coefficient.

21. Apparatus according to claim 20 wherein

$$\alpha = (\alpha' + \text{offset})$$

where  $\alpha' + \text{offset}$  is a function of the data bit to be embedded in the coefficient, and the apparatus is arranged to  
calculate modified coefficient values  $C_i' = C_i + (\alpha' + \text{offset}) \cdot P_i$  where  
 $\alpha' = 0$  if  $S$  is positive and the data to be concealed is a bit of a first value,  
 $\alpha' = 0$  if  $S$  is negative and the data to be concealed is a bit of a second value, and  
otherwise  $\alpha'$  is a function of  $S$  such that  $\sum C_i' \cdot P_i$  has the correct sign to represent the bit to be encoded.

22. Apparatus according to claim 21, wherein the first value is "1" and the second value is "0".

23. Apparatus according to claim 21 or 22 wherein  $\alpha = -S/(L-1)$  or  $-S/L$

24. Apparatus according to claim 20, 21, 22 or 23, wherein the offset is greater than or equal to zero.

25. Apparatus according to claim 25 wherein the offset = 1.

26. Apparatus according to any one of claims 20 to 25, wherein the coefficients are coefficients of a wavelet transform  
of the material.

27. Apparatus according to any one of claims 19 to 24 comprising a generator for generating a UMID as the said data  
to be concealed.

28. Apparatus for removing data from material, which data has been concealed by the apparatus of any one of claims  
20 to 27, the apparatus comprising:

a generator for generating a PRSS; and  
a calculator for calculating  
the correlation  $S' = \sum C_i' \cdot P_i$  for  $i=1$  to  $L$  where  $P_i$  are the bits of the PRSS,  
a value  $\alpha_r$  dependent on  $S'$ , and  
a coefficient value  $C_i = C_i' - \alpha_r \cdot P_i$  to recover the unmodified coefficients  $C_i$ .

29. Apparatus according to claim 26, wherein  $\alpha_r = S'/(L-1)$  or  $(S'/L)$ .

30. Apparatus according to claim 28 or 29, further comprising a decoder for deriving the bits of the concealed data  
from the correlation value  $S'$ , where if  $S'$  is positive a bit of the data has a first value and if  $S'$  is negative a bit of  
the data has a second value.

31. Apparatus according to claim 28, 29 or 30, comprising a synchronizer for synchronizing the generated PRSS with  
the PRSS of the embedded data.

32. A method of embedding data in material, comprising the steps of:

producing transform coefficients  $C_i$  of the material;  
comparing the magnitudes of the coefficients with a threshold value  $T$ ; and  
producing, from the coefficients  $C_i$  and the said data, modified coefficient values  $C_i'$  which are modified by  
respective information symbols of a pseudo random symbol sequence modulated by the said data to be em-  
bedded;

wherein the said step of producing modified coefficient values does not use coefficients of magnitude greater

than the said threshold T and does not use the corresponding information symbols.

33. A method according to claim 32, wherein the modified coefficients

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$$Ci' = Ci + \alpha \cdot Pi$$

where  $\alpha \cdot Pi$  is an information symbol modulated by the data to be embedded,  $\alpha$  being a scaling factor.

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34. A method according to claim 33, wherein  $\alpha$  is dependent on the data.

35. A method according to claim 33, wherein  $\alpha$  is of fixed value.

36. A method according to claim 32, wherein the modified coefficients

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$$Ci' = Ci + \alpha \cdot Ri$$

where  $Ri$  is an information symbol  $Pi$  modulated by the data, and  $\alpha$  is a scaling factor.

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37. A method according to claim 32, 33, 34, 35 or 36, wherein the said transform is a wavelet transform.

38. A method according to claim 32, 33, 34, 35 or 36, wherein the said transform is a spatial frequency transform.

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39. A method for detecting data embedded in material, the detecting method comprising  
receiving transform coefficients of the material;  
comparing the magnitudes of the received coefficients with a threshold value T; and  
correlating, the said coefficients with a respective symbols of a pseudo random symbol sequence to detect  
the said data, wherein the correlating step does not use coefficients of magnitude greater than the said threshold  
T and corresponding symbols of the pseudo random symbol sequence.

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40. A method according to claim 39, further comprising removing the said data from the said received coefficients not  
using coefficients of magnitude greater than said threshold T.

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41. A method of detecting data embedded in material, the method comprising;  
receiving transform coefficients of the material;  
comparing the magnitudes of the received coefficients with a threshold Tclip;  
clipping, to a magnitude Tclip, the magnitude of coefficients of magnitude greater than the said threshold  
Tclip; and  
correlating the clipped and unclipped coefficients with a pseudo random symbol sequence to detect data  
embedded in the material.

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42. A method according to claim 41, further comprising removing data from said clipped and unclipped coefficients.

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43. A method comprising embedding data according to any one of claims 32 to 40 and a method of detecting the data  
according to claim 10 or 11.

44. A method of embedding data in material, the method comprising  
receiving transform coefficients  $Ci$  representing the material;  
comparing the magnitudes of the said transform coefficients  $Ci$  with a threshold Tclip;  
clipping, to the magnitude Tclip, the magnitudes of those of the coefficients having a magnitude exceeding  
Tclip to produce clipped coefficients; and  
producing modified coefficients  $Ci'$  values dependent on a scaling factor and the data to be embedded, and  
the scaling factor is calculated using the said clipped coefficients and the coefficients  $Ci$  of magnitude less than Tclip.

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45. A computer program product arranged to carry out the method of any one of claims 32 to 44 when run on a computer.

46. Apparatus for embedding data in material, comprising:

a transformer for producing transform coefficients  $C_i$  of the material;  
 a comparator for comparing the magnitudes of the coefficients with a threshold value  $T$ ; and  
 a combiner for producing, from the coefficients  $C_i$  and the said data, modified coefficient values  $C_i'$  which are  
 modified by respective information symbols of a pseudo random symbol sequence modulated by the said data  
 to be embedded, wherein the combiner does not use coefficients of magnitude greater than the said threshold  
 $T$  and does not use the corresponding information symbols.

47. Apparatus according to claim 46, wherein the combiner is arranged to produce modified coefficients

$$C_i' = C_i + \alpha \cdot P_i$$

where  $\alpha \cdot P_i$  is an information symbol modulated by the data to be embedded,  $\alpha$  being a scaling factor.

48. Apparatus according to claim 47, wherein  $\alpha$  is dependent on the data.

49. Apparatus according to claim 47, wherein  $\alpha$  is of fixed value.

50. Apparatus according to claim 46, wherein the combiner is arranged to produce coefficients

$$C_i' = C_i + \alpha \cdot R_i$$

where  $R_i$  is an information symbol  $P_i$  modulated by the data, and  $\alpha$  is a scaling factor.

51. Apparatus according to claim 50, comprising a pseudo random sequence generator and a modulator for modulating the pseudo random sequence with the said data.

52. Apparatus according to claim 46, 47, 48, 49, 50 or 51, wherein the said transformer is a wavelet transformer.

53. Apparatus according to claim 46, 47, 48, 49, 50 or 51, wherein the said transformer produces a spatial frequency transform of the said material.

54. Apparatus for detecting data embedded in material, the detecting apparatus comprising  
 an input for receiving transform coefficients of the material;  
 a comparator for comparing the magnitudes of the received coefficients with a threshold  $T$ ; and  
 a correlator for correlating the said coefficients with respective symbols of a pseudo random symbol sequence to detect the said data, wherein the correlation does not use coefficients of magnitude greater than the said threshold  $T$  and the corresponding symbols of the pseudo random symbol sequence.

55. Apparatus according to claim 54, further comprising a data remover for removing data from the receiving coefficients, the remover omitting coefficients of magnitude greater than the said threshold  $T$ .

56. Apparatus for detecting data embedded in material, comprising;  
 an input for receiving transform coefficients  $C_i'$  of the material;  
 a comparator for comparing the magnitudes of the received coefficients with a threshold  $T_{clip}$ ;  
 a clipper for clipping, to a magnitude  $T_{clip}$ , the magnitude of coefficients of magnitude greater than the said threshold  $T$ ; and  
 a correlator for correlating the clipped and unclipped coefficients with a pseudo random symbol sequence to detect data embedded in the material.

57. Apparatus according to claim 56, further comprising a remover for removing data from the clipped and unclipped coefficients.

58. Apparatus for embedding data in material, the apparatus comprising:

an input for receiving transform coefficients  $C_i$  representing the material;  
 a comparator for comparing the magnitudes of the said transform coefficients with a threshold  $T_{clip}$ ;

a clipper for clipping, to the magnitude  $T_{clip}$ , the magnitudes of those of the coefficients having a magnitude exceeding  $T_{clip}$ ; and  
a processor for producing modified coefficients  $C_i'$  values dependent on a scaling factor and the data to be embedded, and the scaling factor is calculated using the said clipped coefficients and the coefficients  $C_i$  of magnitude less than  $T_{clip}$ .

5 59. A system comprising embedding apparatus according to any one of claims 46 to 53 and detecting apparatus according to claim 54, 55, 56 or 57.

10 60. A method or apparatus according to any preceding claim wherein the said data comprises a UMID.

61. A method or apparatus according to any one of claims 32 to 60, wherein the said material comprises video material.

15 62. A method or apparatus according to any one of claims 32 to 61, wherein the said material comprises audio material.

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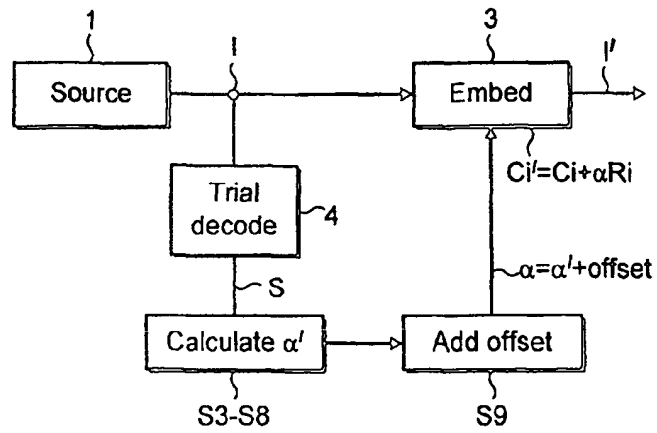


FIG. 1

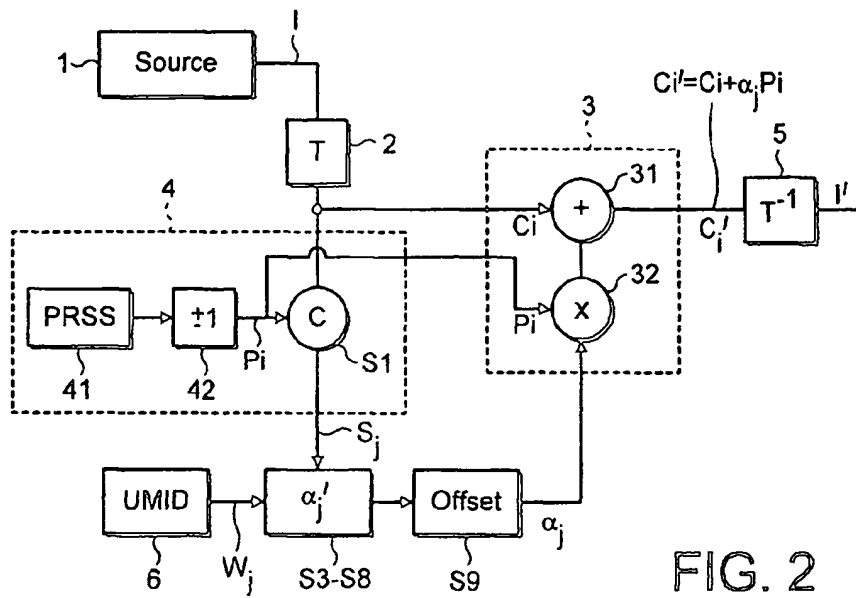


FIG. 2

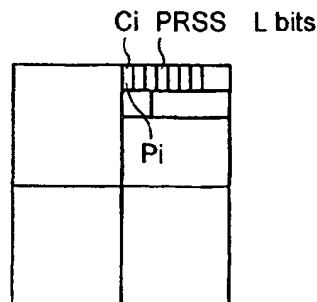


FIG. 3A

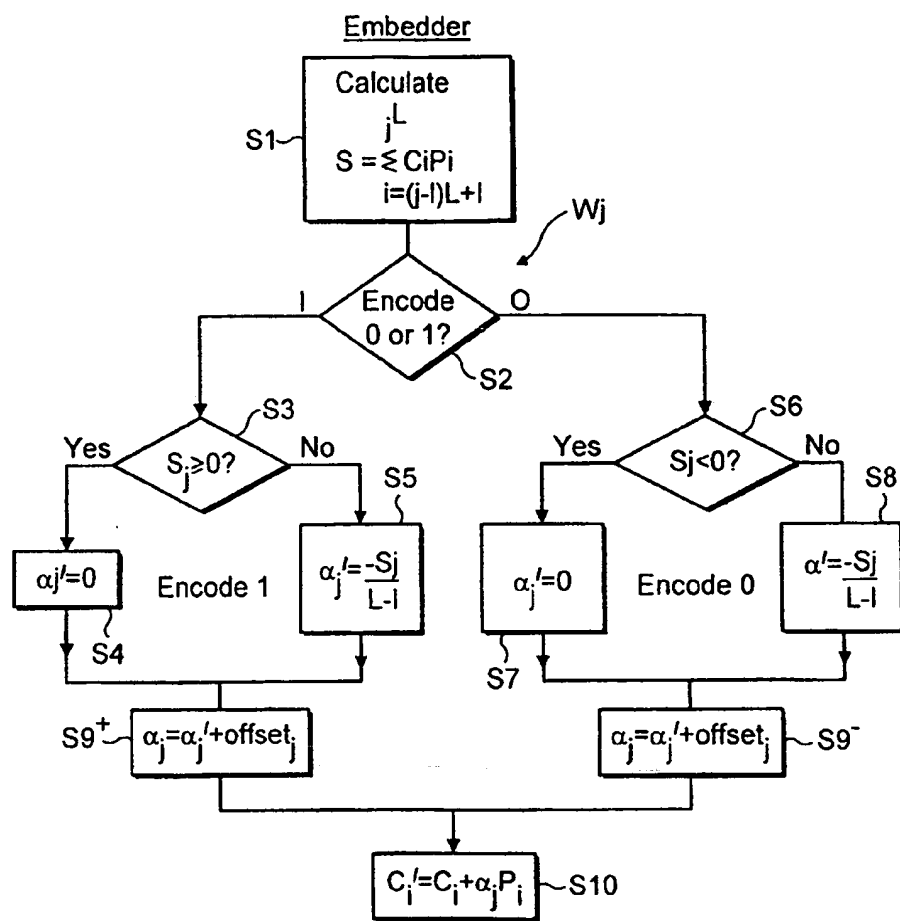


FIG. 3B

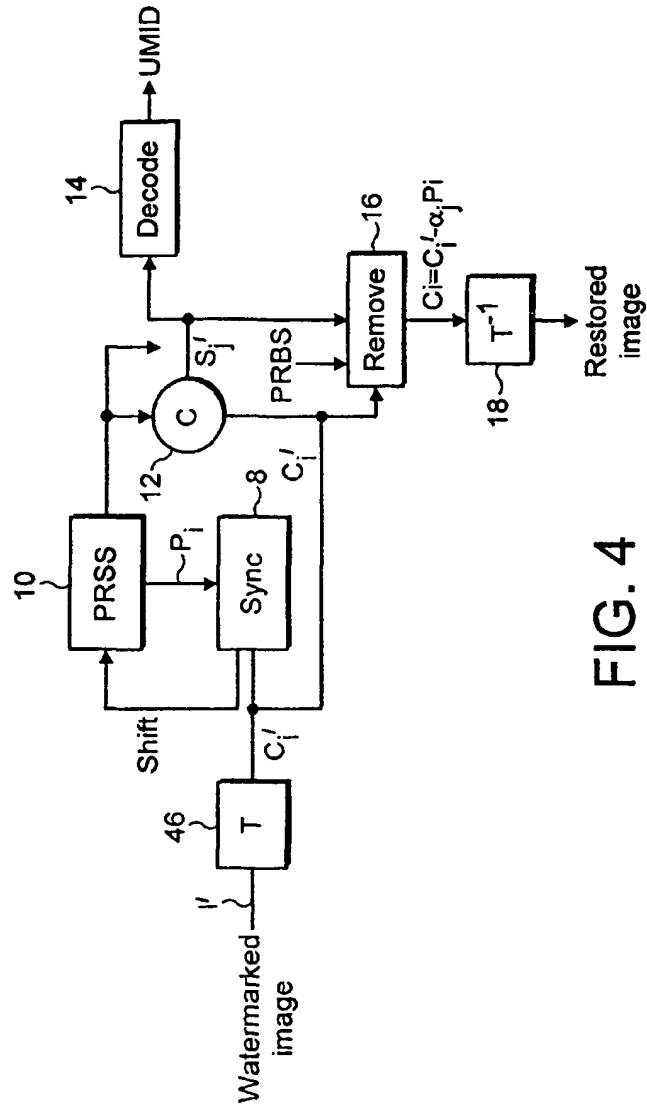


FIG. 4

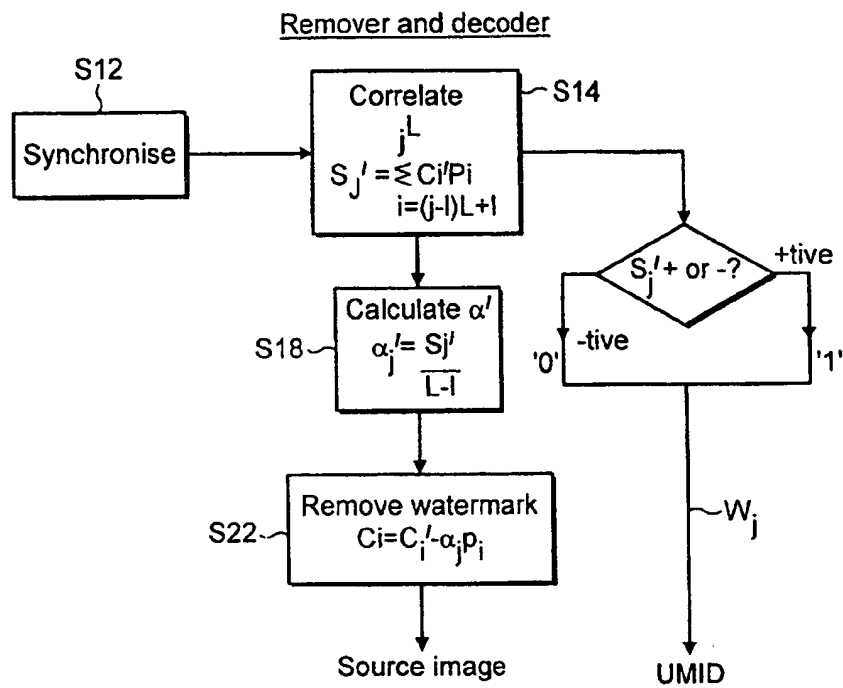


FIG. 5

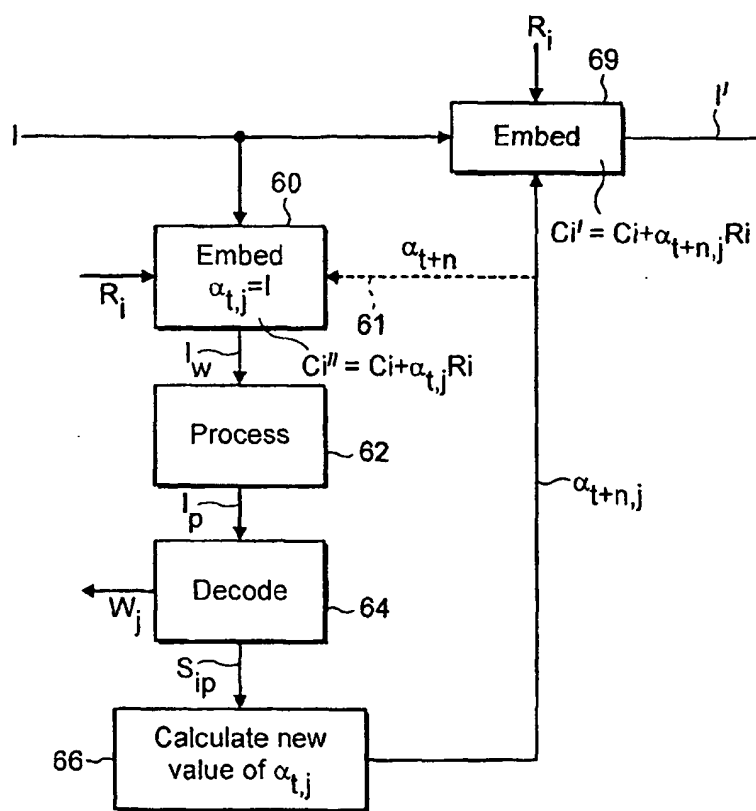


FIG. 6

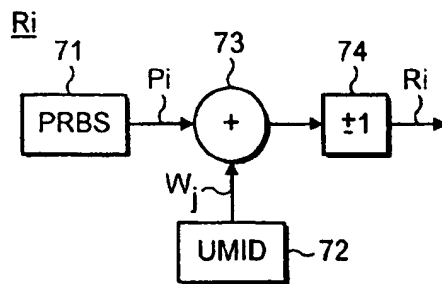


FIG. 7

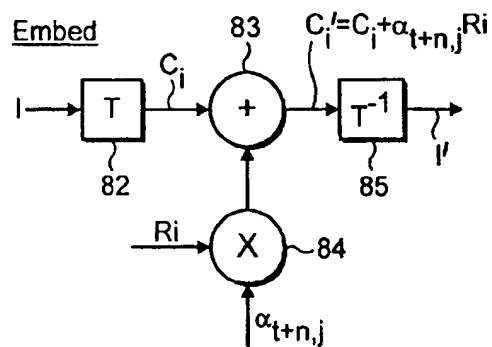


FIG. 8

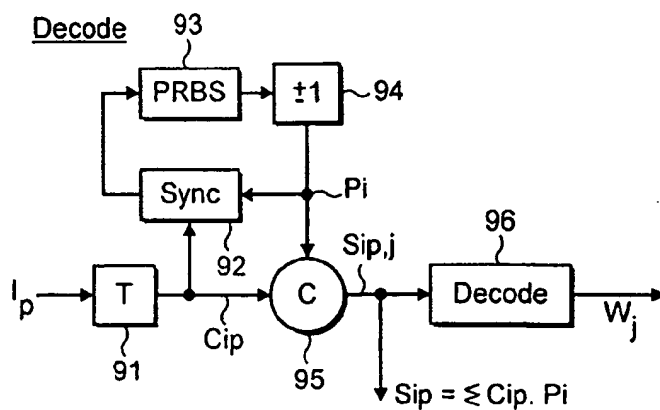


FIG. 9

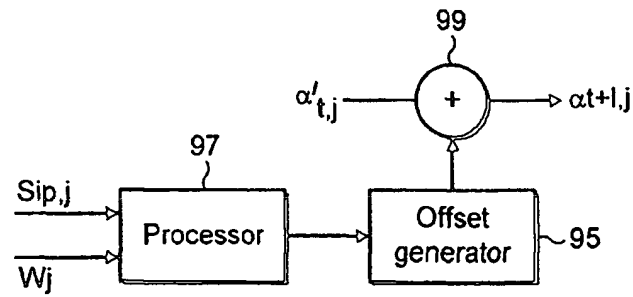


FIG. 10A

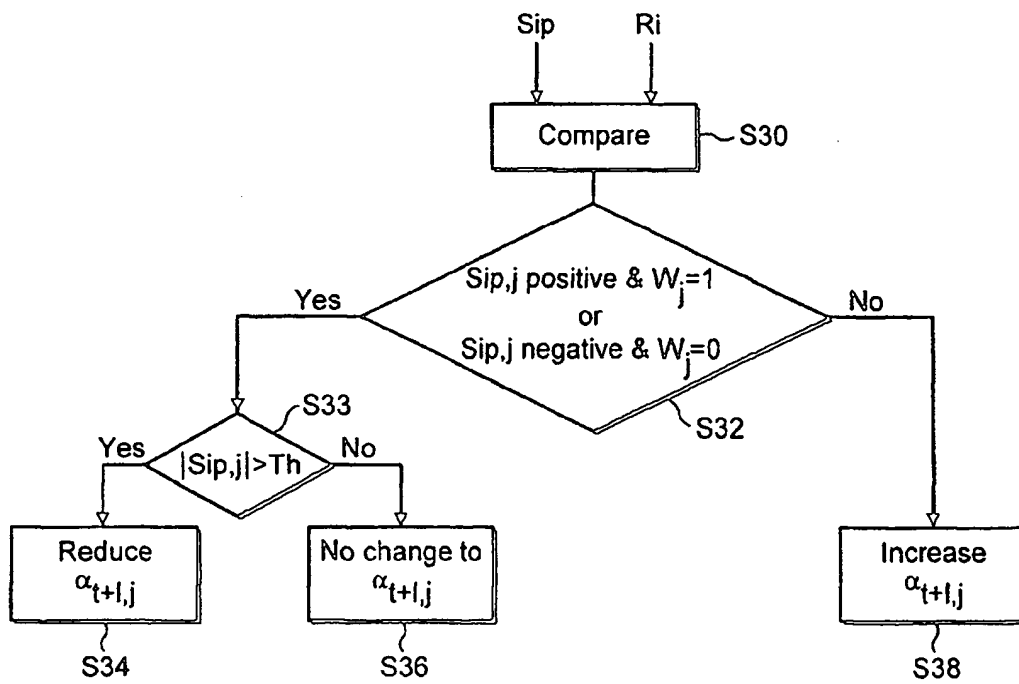


FIG. 10B

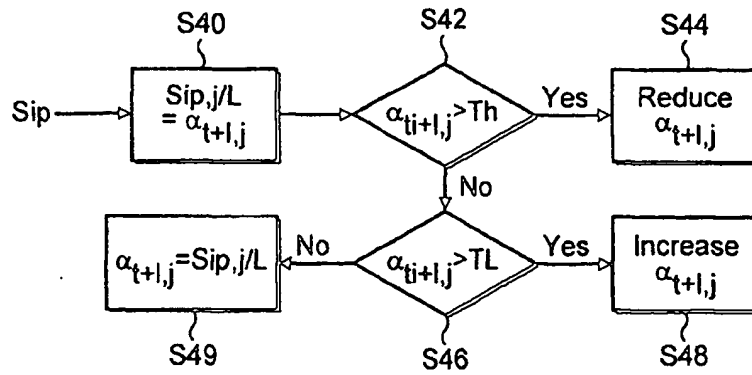


FIG. 10C

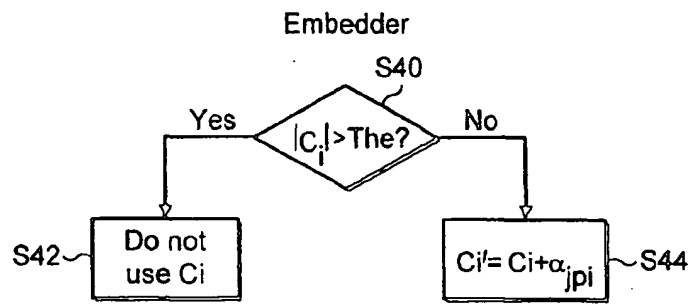


FIG. 11A

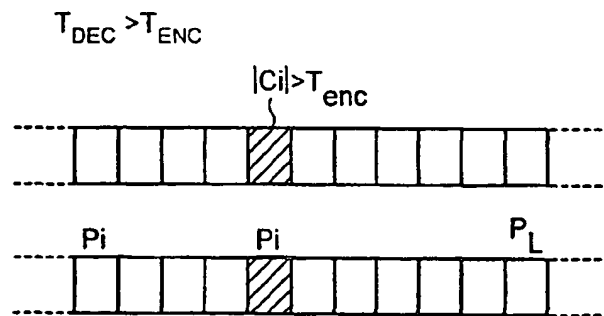


FIG. 11B

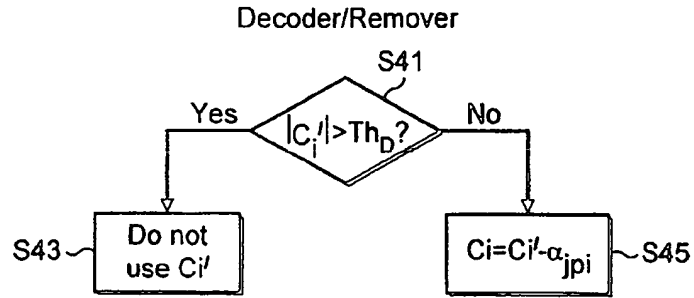


FIG. 12

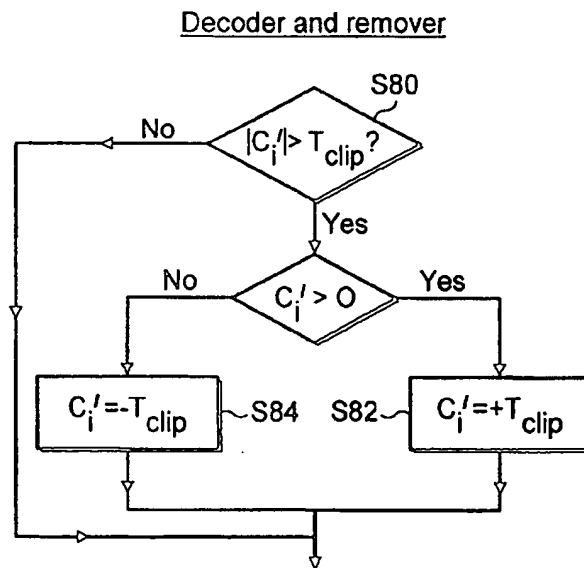


FIG. 13

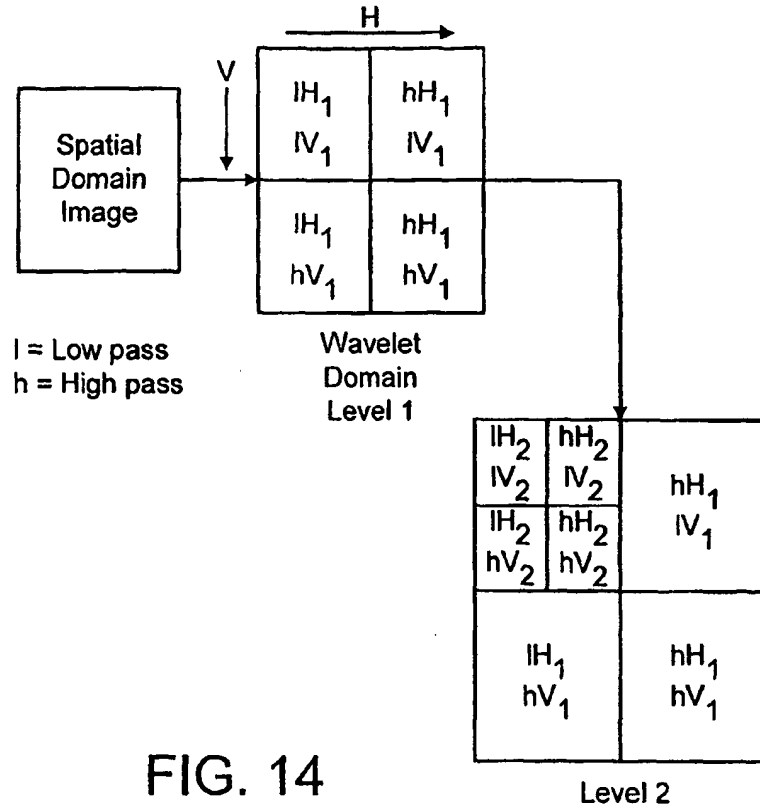


FIG. 14

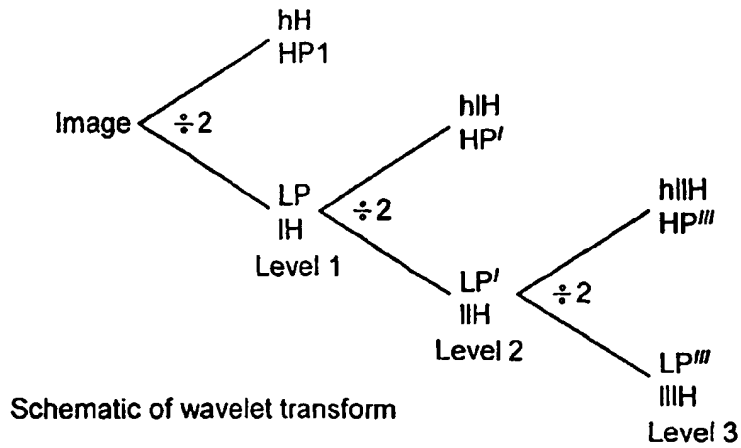


FIG. 15

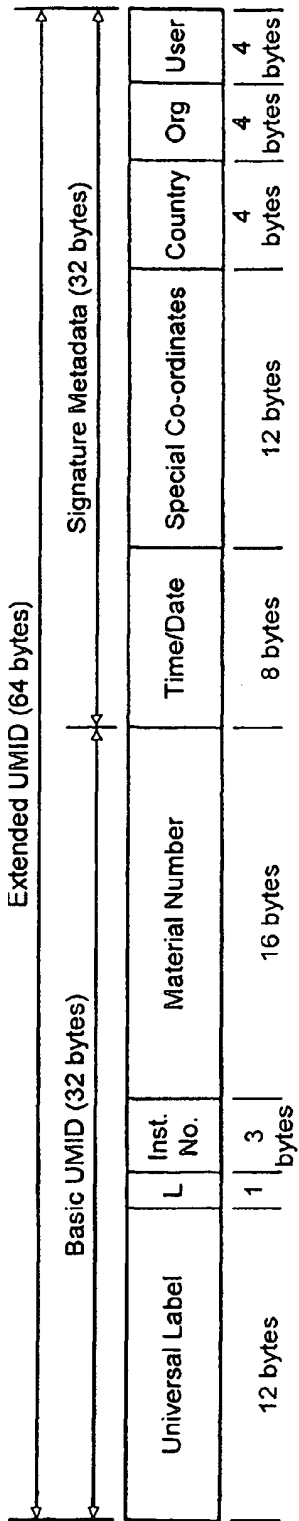


FIG. 16



FIG. 17

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